

Description

LINEAR-IN-DECIBEL VARIABLE GAIN AMPLIFIER

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a variable gain amplifier, and more particularly, to a variable gain amplifier having a gain liner-in-decibel with respect to controlling voltages.

[0003] 2. Description of the Prior Art

[0004] Recently wireless communication systems have been developing very fast. As a result, many kinds of high bandwidth high sensitivity transceivers are proposed. Variable gain amplifiers are often used in this kind of transceiver to broaden the processing range of the system. A variable gain amplifier that has a gain liner in decibel (dB) with respect to controlling voltage(s) has relatively broader gain range.

[0005] Please refer to Fig.1 where a circuit of a conventional vari-

able gain amplifier is illustrated. The variable gain amplifier shown in Fig.1 is a differential amplifier. The voltage gain A_v of the whole circuit can be determined from the half circuit of the differential amplifier. Disregarding the phase, the voltage gain A_v of this variable gain amplifier will be:

$$A_v = \frac{V_{out}'}{V_{in}'} = \frac{K}{1 + \exp\left(\frac{V_y}{V_t}\right)} \quad (1)$$

where K is substantially a constant value.

[0006] From equation (1) it can be seen that the denominator of the voltage gain A_v comprises not only a simple exponential function but also a constant term 1. Consequently, the voltage gain A_v does not have a perfectly exponential relationship with respect to the controlling voltage V_y .

[0007] Please refer to Fig.2. Fig.2 is a graph for showing the relation between the voltage gain A_v and the controlling voltage V_y of Fig.1. Note that when $V_y < V_t$, the voltage gain A_v will not change exponentially with respect to the change in the controlling voltage V_y . The smaller the controlling voltage V_y is, the less the voltage gain A_v will change with respect to the change in the controlling voltage V_y . This phenomenon where the voltage gain A_v does not have perfect exponential relationship with the con-

trolling voltage V_y is caused by the constant term 1.

SUMMARY OF INVENTION

[0008] It is therefore one of the many objectives of the claimed invention to provide a variable gain amplifier that can substantially demonstrate a simple linear-in-decibal relationship of a voltage gain with respect to controlling voltage(s).

[0009] According to the claimed invention, a variable gain amplifier is disclosed. The variable gain amplifier comprises an amplifying stage for generating an output voltage according to an input voltage; and a variable gain stage for adjusting a voltage gain of the amplifying stage according to at least a controlling voltage; wherein the voltage gain is a simple exponential function, and the value of the simple exponential function is determined by the controlling voltage.

[0010] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the embodiments that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF DRAWINGS

- [0011] Fig.1 is a circuit diagram of a conventional variable gain amplifier.
- [0012] Fig.2 is a graph for showing the relationship between the voltage gain A_v and the controlling voltage V_y of Fig.1.
- [0013] Fig.3 is a circuit diagram of a variable gain amplifier according to an embodiment of the present invention.
- [0014] Fig.4 is a graph for showing the relationship between the voltage gain A_v and the difference between the controlling voltages of Fig.3.
- [0015] Fig.5 is a circuit diagram of a variable gain amplifier according to another embodiment of the present invention.

DETAILED DESCRIPTION

- [0016] Please refer to Fig.3 where a first embodiment circuit diagram of a variable gain amplifier of the present invention is illustrated. As shown in Fig.3, the variable gain amplifier 300 includes: an amplifying stage 350 for generating an output voltage V_{out} according to an input voltage V_{in} and a variable gain stage 310 for controlling the value of a voltage gain A_v of the amplifying stage 350 according to a first controlling voltage V_1 and a second controlling voltage V_2 , wherein the voltage gain A_v is the ratio between the output voltage V_{out} and the input voltage V_{in} . The denominator of the voltage gain A_v is a simple exponent-

tial function; the value of the simple exponential function is determined by the difference between the first controlling voltage V1 and the second controlling voltage V2.

[0017] The variable gain stage 310 is a transconductance amplifier for generating a gain current Ig according to the difference between the first controlling voltage V1 and the second controlling voltage V2. In this embodiment, the variable gain stage 310 includes: a first transistor 572 coupled to the first controlling voltage V1; a second transistor 573 coupled to the second controlling voltage V2; a first current source 312 coupled to the emitters of the first transistor 572 and the second transistor 573 to provide a first current I1; a second current source 314 for generating the gain current Ig; a first resistor 594 coupled between the collector of the first transistor 572 and the second current source 314; and a second resistor 595 coupled between the collector of the second transistor 573 and the second current source 314.

[0018] The value of the gain current Ig is determined by the difference between the first controlling voltage V1 and the second controlling voltage V2 and the value of the first current I1. In this embodiment, their relationship is as follows:

$$Ig = I1/[1 + \exp(\frac{V1-V2}{Vt})] \quad (2)$$

[0019] As for the amplifying stage 350, it includes: an input unit 360 for receiving the input voltage V_{in} and generating an input current I_{in} according to the input voltage V_{in} ; a current transforming unit 370 for generating a second current I_2 according to the gain current I_g ; and a transresistance amplifying unit 380 for generating the output voltage V_{out} wherein the value of the output voltage V_{out} is determined by the input current I_{in} and the second current I_2 .

[0020] In this embodiment, the input unit 360 includes an input transistor 571. The input transistor 571 is for generating an input current I_{in} according to the input voltage V_{in} . As for the current transforming unit 370, it includes: a third transistor 574, the collector and the base of which are coupled together; a fourth transistor 575; a third current source 372 coupled to the emitters of the third transistor 574 and the fourth transistor 575 to provide a third current I_3 ; a fourth current source 374 for generating the second current I_2 ; a third resistor 596 coupled between the collector of the third transistor 574 and the fourth current source 374; and a fourth resistor 597 coupled between the collector of the fourth transistor 575 and the

fourth current source 374. Please note that the ratio between the third current I_3 and first current I_1 is substantially the same as the ratio between the second current I_2 and the gain current I_g . In the embodiment circuit diagram shown in Fig.3, if the parameters of the elements of Fig.3 are properly designed, the above requirement can be satisfied.

- [0021] As for the transresistance amplifying unit 380, in this embodiment it includes: a fifth transistor 576, the base and the collector of which are coupled to the base of the fourth transistor 575; a sixth transistor 577, the base of which is coupled to the base of the third transistor 574; a seventh transistor 578, the base and the collector of which are coupled to the emitters of the fifth transistor 576 and the sixth transistor 577; a fifth current source 382 coupled to the input unit 360 and the collector of the fifth transistor 576 to provide a fifth current I_5 ; and an output resistor 598 coupled to the collector of the sixth transistor 577 to generate the output voltage V_{out} .
- [0022] Consider the variable gain amplifier 300 as a whole, the function of which is to amplify the input voltage V_{in} to obtain the output voltage V_{out} . The ratio between the output voltage V_{out} and the input voltage V_{in} , that is the

voltage gain A_v , is as follows:

$$A_v = \frac{V_{out}}{V_{in}} = \frac{K}{\exp\left(\frac{V_1 - V_2}{V_t}\right)} \quad (3)$$

[0023] where K is substantially a constant value.

[0024]

[0025] The term

$$\exp\left(\frac{V_1 - V_2}{V_t}\right)$$

[0026] of equation (3) is the simple exponential function mentioned above; the value of which is determined by the difference between the first controlling voltage V_1 and the second controlling voltage V_2 . Please refer to Fig.4. Fig.4 is a graph for showing the relationship between the voltage gain A_v and difference between the controlling voltages of Fig.3. Compared with Fig.2, it is obvious that in Fig.4 the voltage gain A_v has an authentic exponential relationship with the difference between the first controlling voltage V_1 and the second controlling voltage V_2 .

[0027] Please refer to Fig.5. Fig.5 is a second embodiment circuit

diagram of a variable gain amplifier of the present invention. The difference between Fig.5 and Fig.3 is that NMOS transistors in Fig.3 are replaced by PMOS transistors in Fig.5, PMOS transistors in Fig.3 are replaced by NMOS transistors in Fig.5, NPN type BJTs in Fig.3 are replaced by PNP type BJTs in Fig.5, and PNP type BJTs in Fig.3 are replaced by NPN type BJTs in Fig.5. However, the basic operating principle remains the same.

- [0028] In actuality, the embodiments shown if Fig.3 and Fig.5 not only can be used alone for amplifying a voltage signal, but each of them can also be used as a half circuit of a differential amplifier.
- [0029] Those skilled in the art will readily observe that numerous modification and alternation of the device may be made while retaining the teaching of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.